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Lab. Project IED-20
Final Report

Investigation of Platings of Electrical Contacts

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Physical Sciences Division

U. S. NAVAL APPLIED SCIENCE LABORATORY
BROOKLYN, NEW YORK

INVESTIGATION OF PLATINGS
OF
ELECTRICAL CONTACTS

8 April 1968

Lab. Project IED-20
Final Report

Albert Glowasky

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BROOKLYN, NEW YORK, 11251

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ABSTRACT

The relative deterioration of noble metal platings for electric contacts by marine atmospheres has been determined in the interests of improving the reliability of electrical connections and conserving precious metals. As part of a cooperative effort with EIA, P-5.1 Committee Research Laboratories, this Laboratory investigated the effects of marine and laboratory salt spray atmospheres on various contact platings in order to determine optimum platings. Emphasis is given to the effect of silver underplating. Work described includes establishment of experimental techniques, equipment development, the marine exposure site at Ft. Tilden, N.Y., the laboratory salt spray environment and procedures. The results with the various platings were summarized and show that nickel underplating is undesirable, 30 millionths of gold over 100 millionths of silver is superior and 30 millionths of gold over 100 millionths of copper is adequate for Naval applications in a marine atmosphere.

SUMMARY

The increasing usage of separable connectors in large quantities for electrical and electronic communications has pointed up a need for study of contact materials having high reliability and low contact resistance especially when exposed to a marine environment as required for Naval use. A search of the literature reveals little information on the properties and performance of electroplated contact metals when exposed to marine environmental contaminants. The Naval Applied Science Laboratory in cooperation with the Bell Telephone Laboratories, Murray Hill, N.J. and the Electronic Industries Association P-5.1.4 Committee on Contact Plating formulated a program for determining optimum contact platings for application in a marine environment.

MIL-C-26636 size #16 and #20 pin and socket contacts were electroplated with gold over silver, gold over nickel, gold over copper, rhodium over nickel and rhodium over silver. Plated contacts were wired and assembled in a modified louvered Stevenson Screen and installed at the NASL marine environmental site at Ft. Tilden, N.Y. mounted on a supporting structure facing the ocean without obstruction, approximately 300 feet from the shore line and 40 feet above M.L.W. A second group of size #20 plated contacts were wired and assembled on a stainless steel stand and installed in the NASL salt spray environment.

Analysis of tarnish films deposited on exposed copper plates during the exposure period at the Ft. Tilden test site indicated a suitable marine environment free of sulphide contamination.

Twenty-two months of marine exposure at Ft. Tilden, N.Y. produced no appreciable change in the resistances of gold over silver and gold over copper plated electrical contacts. The resistances of the gold over nickel and rhodium over nickel plated contacts more than doubled within 400 hours of salt spray fog exposure and then proceeded to increase exponentially thereafter.

The results indicated that nickel underplating is undesirable, 30 millionths of gold over 100 millionths of silver is superior and 30 millionths of gold over 100 millionths of copper is adequate for Naval applications in a marine atmosphere.

The adequacy of gold over copper plating indicates that conservation of precious silver and substantial savings can be accomplished through the use of electrical contacts without silver underplating.

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ADMINISTRATIVE INFORMATION

Ref: (a) NASL Technical Director's Memo of 5 Oct 1965
(b) NASL Technical Director's Memo 901C:JMR 3920 of 21 Apr 1966
(c) NASL Project IED-20 Program Summary dated 1 May 1966
(d) Lab. Project IED-20, Technical Memo 1, Investigation of Platings on Electrical Contacts of 8 Jul 1966
(e) Lab. Project IED-20, Status Report No. 2; NASL Annual In-House Independent Exploratory Development Program Report for Period Ending 31 Dec 1966

1. As directed by references (a) and (b) and in accordance with the objectives set forth in reference (c), the Naval Applied Science Laboratory conducted a study to develop techniques to determine the efficacy of various types of electroplatings on electrical contacts under marine and laboratory salt spray environmental exposure for Naval use. The work reported herein was formerly covered by Subproject SF 021-02-02, Task 9633.

ACKNOWLEDGMENTS

2. This work was performed by A. Glowasky under the general supervision of G.J. Thompson, Head, Electrical Branch. The technical assistance rendered by R.G. Baker of Bell Telephone Laboratories, C. Stuart of Amphenol Corp., A. Nash of Burndy Corp., R. Tweed of Nu-Line Industries and S. Weiss of Elco Corp., is acknowledged.

OBJECT

3. The objective of this investigation is to develop techniques to determine the efficacy of various types of contact platings, to investigate the effects of laboratory developed salt spray environment as compared with those caused by marine environment and to determine optimum contact platings for Naval applications.

INTRODUCTION

4. Reliability studies have shown that electrical connectors produce the largest portion of failures in electrical and electronic circuits. Physical size limitations in low power circuits, which is the area of concern, generally restrict connector improvements to contact configurations, surfaces and materials. Currently, improvements are concentrated on noble metal electroplatings of electrical contacts and are based on incomplete information on electrical performance and durability. In these attempts at improvement, such platings as 0.000030 inch gold over 0.00020 inch silver and up to 0.0015 inch hard gold are specified in various military and industrial procurement documents. Suitable evidence of material with minimum thicknesses for reliable wear and low contact resistance, particularly at low voltage levels, and capable of operation under industrial and especially marine environments, has not been firmly established. The requirements for commercial applications may be met

without the use of silver underplating, a feature tentatively considered necessary for inhibiting corrosion in a marine atmosphere. Evidence was needed to demonstrate whether or not this feature is necessary for Naval application. For these reasons the Electronic Industries Association, P-5.1 Committee on Electrical Contacts, in which this Laboratory participated, formulated a program for determining optimum contact platings. This Laboratory conducted the investigation on contact platings in a marine atmosphere for Naval application. This report presents the design of the planned experiment to establish the plating requirements for a marine environment. A detailed description of the methodology and techniques essential to cooperating laboratories in correlating their work. The results compiled from field and laboratory environments are analyzed and recommendations are made.

APPROACH

5. The Navy's interest in the electroplating of electrical contacts is unique in that it concerns performance under a marine corrosion environment. The Naval Applied Science Laboratory in cooperation with Electronics Industry Association P-5.1.4 Committee on Electrical Contact Platings formulated plans for a program to determine the optimum plating for such contacts and this required the development of experimental techniques, equipment and procedures that would be employed by all participating laboratories regardless of the environment with which each was concerned.

6. The committee established the following guide lines and objectives for its program:

a. The primary aim was confined to electroplatings of electrical contacts and not contact geometry or contact life.

b. The development of methodology to determine the efficacy of various types of platings.

c. Investigation of exposure sites and their relationship to the application environments namely:

1. Industrial - Urban
2. Sulfurous
3. Elevated temperature
4. Marine

In addition NASL agreed to conduct an investigation of the effect of laboratory salt spray on the plating of electrical contacts. It was important to select for study, one type of basic metal for the contact preferably from one manufacturer and one geometry of contact. This eliminated as many variables as possible from the experiment to facilitate correlation between cooperating laboratories. While it is recognized that investigation of wear and possible advantages of lubrication should be considered for future study when results have established one or several good finishes for each environment, these will not be covered as part of this program.

7. The study under marine corrosion environment and laboratory salt spray conditions was undertaken by the Naval Applied Science Laboratory. The environmental study utilizing industrial-urban atmosphere was assigned to Bell Telephone Laboratories while the sulfurous atmosphere was assigned to Burndy Research Division.

8. In order to keep the size of the exploratory program manageable while providing the maximum amount of useful information with the minimum number of specimens, it was agreed to study the following nine combinations of platings on size #16 and size #20 MIL-C-26636 type pin and socket contacts.

a. Gold over Silver:

(1) Gold 30×10^{-6} inches over Silver 100×10^{-6} inches

(2) Gold 100×10^{-6} inches over Silver 100×10^{-6} inches

(3) Gold 50×10^{-6} inches over Silver 200×10^{-6} inches

b. Gold over Nickel:

(1) Gold 30×10^{-6} inches over Nickel 100×10^{-6} inches

(2) Gold 100×10^{-6} inches over Nickel 100×10^{-6} inches

c. Gold over Copper:

(1) Gold 30×10^{-6} inches over Copper 100×10^{-6} inches

(2) Gold 100×10^{-6} inches over Copper 100×10^{-6} inches

d. Rhodium over Nickel:

(1) Rhodium 20 to 30×10^{-6} inches over Bright Nickel 100×10^{-6} inches

e. Rhodium over Silver:

(1) Rhodium 20 to 30×10^{-6} inches over Silver 100×10^{-6} inches

9. Amphenol Corporation furnished a sufficient number of size #16 and #20 unplated pin and socket contacts manufactured from their leaded copper full hard alloy 126, for the study.

10. Nu-Line Industries plated all the contacts in accordance with Bell Telephone Labs requirements indicated in BTL Specification WL-2250.101, Issue 8 for Electroplated Finishes.

11. Upon receipt of all the electroplated contacts at NASL, no effort was made to chemically or otherwise clean them since they were to be handled in the normal manner as would electroplated contacts received from any contact manufacturer. However, precautionary measures were taken to avoid further contamination of the specimens by crimping and wiring them in a clean controlled atmosphere room with the technicians using disposable vinyl examination gloves when handling the electroplated contacts and their related components.

PROCEDURE

12. Approximately 14 specimen contacts were withdrawn from each size and type of plating for plating thickness measurements. These were first measured with the Betascope using the Beta Ray method and then sectioned for verification measurement with a toolmaker's microscope.

13. Twenty plated contacts were allotted for each size and type of contact for each environment as indicated in Figure 1. Each pin and socket contact was crimped to two separate conductors (one current lead and the other a voltage lead). A Buchanan MS3191-1 crimping tool with a MS3191-20A positioner for the two size #24 wires and a MS3191-16A positioner for the two size #22 wires was utilized to perform all the crimping of the respective 2 wire conductors to each plated contact. The best combination of conductors was experimentally determined to be two #22 stranded wires for the size #16 contact and two #24 stranded wires for the size #20 contact. Navy Type E MIL-W-16878/4A 7 strand, white teflon insulated wire was used throughout. The opposite ends of the two wires emanating from each pin and socket contact were soldered into a 50 contact Amphenol connector pt. No. 57-20500. Ten such pin and socket contacts wired with forty conductors were soldered to each Amphenol 50 contact connector. Ten of these contacts were mated once prior to installation in the field environment while the remaining ten contacts were mated 100 times at a rate not exceeding one engagement every five minutes. This relatively long interval between engagements avoids possible overheating and relieves stresses of the contact surfaces. The mating of the contacts was accomplished by a specially designed reciprocating mechanism as shown in Figure 2, which was automated to permit 10 pin and socket contacts to be mated repetitively once every five minutes with a mating cycle of insertion and withdrawal of 10 seconds. Ten wired mated contacts were connected into a 10 position transfer switch through which their resistances were measured by a Keithley Model 502A Milliohmeter. During cycling, resistance measurements were made on the contacts after every 25th cycle of engagement, utilizing a 4 wire contact measuring circuit.

14. Each group of 10 wired pin and socket contacts was then mounted in a plastic fixture. These fixtures measured 2 3/4" wide x 2 1/2" high x 4" long and were constructed of 1/4" thick epoxy glass, assembled with stainless steel non-magnetic

screws. Thirty-six such fixture assemblies were prepared for the 9 different types of electroplated contacts, namely 18 fixtures of size #20 contacts and 18 fixtures of size #16 contacts. All 36 wired fixtures were mounted on a stainless steel stand measuring 15" wide x 19" long x 12 5/8" high. Wired fixtures are shown in Figure 3. The complete wired assembly was shock mounted on 4 layers 1/4" thick isomode pads. This was done to avoid mechanical disturbance of any films that would form in the contact area. The assembly was housed in a louvered aluminum shelter, 30" x 30" x 19" similar to a Stevenson Screen and mounted on an aluminum base 36" x 48" x 1/4" thick. One inch thick glass wool filters behind the louvers permitted a free circulation of air but restricted dust particles from contaminating the contact specimens. The enclosure was hinged to the base plate to permit periodic examinations of the contacts. The electrical contact terminations in the 36 fifty contact Amphenol connectors were mounted on a stainless steel terminal rack in front of the exposure housing as shown in Figure 4 and protected by an aluminum cover sealed to the base by a neoprene gasket. In addition numbered electrolytic copper panels 1/2" x 1" x 1/32" thick prepared by Bell Telephone Laboratories were mounted along side the stainless steel stand with glass thread as shown in Figures 3 and 4. These copper panels were removed at monthly intervals and returned to Bell Telephone Laboratories where the amount and types of tarnish films were analyzed. By exposing a set of these panels at the start of this study and measuring the tarnish rate, it is possible to compare the corrosiveness of the environment of this study with that of another no matter when they are started. This technique also allows the study of climatic variations from year-to-year.

15. Upon completion of the assembly, the entire shelter was transported to the Marine field exposure site at Ft. Tilden, N.Y. and shock mounted on 5 layers of 1/4" isomode pads, two feet above ground on a special supporting structure facing the ocean without obstruction approximately 300 feet from the shore line and 40 feet above M.L.W. as shown in Figure 5.

16. Periodic resistance measurements were recorded on all 360 plated specimen contacts mounted within the modified Stevenson Screen enclosure at the marine exposure site during the 22 month exposure period.

17. After 17 months of exposure from January 1966 to June 1967, there was ample evidence of salt spray corrosion to components of the external supporting structure, however, no salt spray corrosion was noted within the Stevenson Screen enclosure. It therefore appeared evident that the salt laden atmosphere must have consisted of salt and moisture in such particulate form and size as to have been prevented by the glass wool filter from entering the enclosure holding the specimens. These filters were therefore replaced with type 316 stainless steel wire screening 0.009" diam. wire, 18x18 mesh which then permitted a freer entry of the salt laden marine atmosphere but prevented insects and debris entering the contact specimen area as shown in Figure 6.

18. A similar stainless steel stand was assembled with only 18 fixtures of 10 wired contacts each of size #20 contacts. For each type of plating, 10 of these contacts were mated only once while the remaining 10 contacts were mated 100 times. These contacts were wired identically to those installed at the exposure site at Ft. Tilden, N.Y.

19. The completed assembly was shock mounted on 4 layers of 1/4" isomode pads onto a 1/4" stainless steel base and installed in a modified laboratory salt spray environment as shown in Figure 7.

20. This assembly of 180 plated contacts was then subjected to the salt spray fog (corrosion) utilizing a 5% salt solution as outlined in method 101C of MIL-STD-202C. In order to utilize maximum corrosion time, the contacts were subjected to the salt spray fog corrosion for 64 hours, rinsed and washed in tap water for several hours, then dried for 24 hours after which time contact resistance measurements were recorded. The electrical contacts were again submitted to the salt spray fog corrosion for another 48 hours, rinsed and washed in tap water, dried and contact resistance measurements recorded. This was all accomplished in a 7 day period. This procedure was repeated continuously until the electrical contacts were subjected to a total of 4000 salt spray fog hours with electrical contact resistances being recorded at the end of each salt spray corrosion period.

RESULTS

21. The unplated contacts furnished by Amphenol Corp. were plated by Nu-Line Industries in accordance with the plating schedule indicated in Figure 1. Results of these platings shown *in Table 1 indicate* a wide variation in plating thickness for each plating requirement. These variations were recognized and tolerated because they are representative of the present state-of-the-art of plating. The uniformity of plating is difficult to control because of variables in plating solutions, temperatures, current density, cleanliness and quantity of contacts involved.

22. The resistance measurements of the plated contacts which were preconditioned for 100 cycles showed only slight variation in contact resistance during the insertion and withdrawal matings. There was no significant difference in the average contact resistance of the contacts that were mated 100 times as opposed to those that were mated only once, but with one exception. The contacts that were plated with rhodium over nickel and were mated 100 times showed an average contact resistance approximately 30% higher than the contacts that were mated only once.

23. The data on the amount of tarnish films found on the copper panels exposed at the Ft. Tilden exposure site given below are in Ångstroms and should only be considered significant to the nearest 100 Å for this purpose. The composition and thickness of the films of these panels was determined by the cathodic reduction method.

Removal Date	Panel No.	Cuprous oxide Ångstroms	Cupric oxide Ångstroms
2/8/66	1	173	0
3/10/66	2	625	60
4/11/66	3	565	118
5/12/66	4	520	107
6/9/66	5	577	149
7/7/66	6	657	149
8/11/66	7	692	328
9/7/66	8	857	83
10/14/66	9	1695	113
11/16/66	10	1775	179
12/15/66	11	2363	0
2/15/67	12	2929	0
3/27/67	13	4427	0
4/20/67	14	5630	0
5/18/67	15	5096	0
6/21/67	16	6138	0

It is known that corrosion films do not form uniformly over the entire surface of the panel. However, in order to report an apparent thickness, one must assume uniformity of tarnish films, because of the possibility of slightly different rates of formation on an individual panel. Seeming anomalies such as panels 2 and 3 can occur and should not be of concern. There is no indication of any sulphide tarnish films which indicates a suitable marine environment free of sulphide contamination.

24. The data obtained at the Ft. Tilden site have been summarized in Table 2. The data taken for the Laboratory Salt Spray conditions have been summarized in Table 3. Seventeen months of sea side exposure, from January 1966 to June 1967 produced no appreciable change in contact resistance according to the measurements shown in Table 2. Examination of the interior of the screened area showed no visual evidence of salt corrosion.Tests were then made by swabbing all interior surfaces with sterile cotton swabs wetted with distilled water. These were chemically analyzed for presence of sodium chloride with a silver nitrate solution. Results showed that there was no sodium chloride present within the screened enclosure. There was however ample visual evidence of salt spray corrosion to components of the external supporting structure. It was therefore concluded that the salt laden atmosphere consisted of salt and moisture in such particulate form and size that it had been prevented from entering the specimen enclosure by the glass wool filters shown in Figure 5. These filters were therefore replaced with a stainless steel mesh screen filter shown in Figure 6 in order to permit the salt laden marine atmosphere to come in contact with the plated specimen contacts. Subsequent measurements made during the period June 1967 to November 1967 indicate a slight increase in

resistance of the gold over nickel and rhodium over nickel plated specimens while no significant change was noted in the gold over silver and gold over copper plated specimens as shown in Table 2.

25. The resistance of the gold over nickel and rhodium over nickel plated specimens more than doubled within the first 400 hours of exposure to Laboratory Salt Spray. After 400 hours, this increase became exponential with time. Under the same conditions the gold over silver and gold over copper plated specimens showed no significant increase in resistance for the entire 4000 hours of exposure.

26. Prior to the removal of the glass wool filters from the Stevenson Screen enclosure in June 1967 there was noted only copper oxide corrosion of the small copper monitoring panels. However after the glass wool filters were replaced with the stainless steel mesh screen filters there was definite visual evidence of green (copper chloride) corrosion indicating the presence of salt.

CONCLUSIONS

27. The copper corrosion panels data show no indications of atmospheric sulphide, while there is ample evidence of salt spray corrosion of the structure fittings indicating that the site is suitable for marine exposure without industrial atmospheric contamination.

28. The absence of salt spray corrosion within the Stevenson Screen enclosure with glass wool filters for the 17 month exposure period to June 1967 was investigated by swabbing all interior surfaces with sterile cotton swabs wetted with distilled water. A chemical analysis of these swabs with silver nitrate solution showed no trace of sodium chloride. An analysis of the copper corrosion panels during this same period also indicated the absence of sodium chloride corrosion. However with the replacement of the glass wool filters with the stainless steel mesh screen filter, there was definite visual evidence of salt spray corrosion within the enclosure and by the green corrosion deposits on the copper corrosion panels. It was therefore concluded that the salt laden atmosphere consisted of salt and moisture in such particulate form and size so as to be prevented from entering the specimen enclosure by the glass wool filters.

29. The 100 cycles of insertion and withdrawal preconditioning did not significantly affect the contact resistance of the gold palted specimens.

30. The results of exposure of plated contacts at the Ft. Tilden, N.Y. marine environment and in the Laboratory Salt Spray environment indicated that nickel underplating is undesirable because of the relatively high increase in resistance in the contacts with gold over nickel and rhodium over nickel underplating. There was no significant increase in resistance in the gold over silver and gold over copper plated contacts, therefore while 30 millionths of gold over 100 millionths of silver is superior, 30 millionths of gold over 100 millionths of copper is adequate for Naval applications in a marine atmosphere. Conclusions as to the adequacy of these gold platings are made with due regard to the inherent variations in such platings produced by even the best current commercial practice. As Table 1 shows there are overall variations in gold thicknesses ranging from about 80 percent above the nominal to 50 percent below the nominal 30 millionths of an inch. The stable contact resistances maintained in corrosive atmospheres by specimens with the gold platings overlaying substrates susceptible to salt corrosion indicates that these platings were non-porous. The conclusions as to the adequacy of platings are therefor conditional on the plating quality or porosity as well as the actual thickness as represented by the lower limit in the variation of plating thickness shown in the report.

31. The results have shown that although there was evidence of salt spray corrosion within the Stevenson Screen enclosure after the installation of the stainless steel mesh screen from June to November 1967, there was no significant change in the resistances of the various plated contacts and therefore there can be no correlation between the results obtained at the Marine exposure at Ft. Tilden and at the Laboratory Salt Spray environment at this time.

RECOMMENDATIONS

32. In view of the adequate performance of the gold over copper plated contacts in a marine and laboratory salt spray environment, it is recommended that silver underplating no longer be required for Naval applications. Under normal conditions of actual use as represented by the repeated matings described in this investigation the plating of 30 millionths of gold over 100 millionths of copper is recommended.

33. Although a comparison of the results of exposure of the contacts to a marine environment and laboratory salt spray does not indicate the degree of acceleration of corrosion attributable to the laboratory salt spray, the poor performance of nickel underplated contacts under laboratory salt spray indicates a possible source of failure. It is therefore recommended that nickel underplating be avoided, where possible, for Naval shipboard applications.

34. It is recommended that the methods and procedures adopted for this investigation be used as guide lines in the study of plating of electrical contacts under, Industrial-Urban, Sulfurous and Elevated Temperature environments so that the results of all investigations can be correlated.

35. In a marine environment where salt spray atmosphere corrosion is to be studied, it is recommended that a modified Stevenson Screen enclosure with type 316 stainless steel mesh screen filter be utilized in lieu of glass wool filter in order to permit the passage of salt laden atmosphere which has been shown to be in particulate form.

TABLE 1

THICKNESS MEASUREMENTS OF PLATED CONTACTS

LOT	PLATING REQUIREMENTS	Thickness X 10^{-6} Inches										
		* BETA SCOPE				MICROSECTION						
P20S1G3	Gold .000030" over Silver .0001" **						Gold			Silver	
		Silver	146	168	152	41	43	40	216	230	197
		Only	172	145	-	41	46	44	228	232	252
S20S1G3	Gold .000030" over Silver .0001" **						Gold			Silver	
		Silver	110	178	165	26	28	35	170	187	157
		Only	142	155	-	21	19	21	170	171	168
P20S1G1	Gold .0001" over Silver .0001"	Microsection Only					Gold			Silver	
						168	183	159	223	257	226
						147	146	157	254	260	259
S20S1G1	Gold .0001" over Silver .0001"	Microsection Only					Gold			Silver	
						78	113	81	151	162	148
						116	83	93	149	114	103
P20S2G5	Gold .000050" over Silver .0002" **						Gold			Silver	
		Silver	232	227	248	56	52	59	383	367	430
		Only	242	270	-	47	69	63	377	419	428
S20S2G5	Gold .000050" over Silver .0002" **						Gold			Silver	
		Silver	205	242	238	47	46	47	454	447	422
		Only	195	298	-	45	47	40	363	377	384
P20N1G3	Gold .000030" over Nickel .0001"						Gold			Nickel	
		33	22	28	21	39	35	36	123	132	116
		23	31	31	35	36	33	36	126	137	132
S20N1G3	Gold .000030" over Nickel .0001"						Gold			Nickel	
		27	37	23	26	16	30	33	148	142	159
		36	27	23	24	20	27	31	134	162	167
P20N1G1	Gold .0001" over Nickel .0001"						Gold			Nickel	
		97	96	107	102	113	120	105	152	158	141
		86	112	93	94	122	113	117	154	144	151

* Instrument limits measurements to overlays only except as otherwise noted.

** Gold omitted from specimens prepared for Beta Scope measurements (see Figure 1)

TABLE 1

THICKNESS MEASUREMENTS OF PLATED CONTACTS

LOT	PLATING REQUIREMENTS	Thickness X 10^{-6} Inches: * BETA SCOPE				MICROSECTION					
S20N1G1	Gold .0001" over Nickel .0001"	100 86	103 102	116 94	112 92	114 128	Gold 133 94	135 121	112 152	Nickel 145 101	163 149
P20C1G3	Gold .000030" over Copper .0001"	32 27	32 28	25 27	32 34	38 36	Gold 46 30	43 29	120 123	Copper 127 122	131 126
S20C1G3	Gold .000030" over Copper .0001"	43 32	32 34	39 38	42 36	33 27	Gold 30 30	31 40	113 127	Copper 120 72	62 65
P20C1G1	Gold .0001" over Copper .0001"	117 103	92 110	116 96	102 96	108 119	Gold 123 152	141 134	41 51	Copper 40 115	120 111
S20C1G1	Gold .0001" over Copper .0001"	125 97	98 101	92 93	111 101	101 107	Gold 92 108	102 126	127 111	Copper 122 119	120 126
P20N1R2	Rhodium .000020" to .000030" over Nickel .0001"	45 43	31 37	35 41	39 43	41 37	Rhodium 34 36	37 36	156 141	Nickel 145 187	197 192
S20N1R1	Rhodium .000020" to .000030" over Nickel .0001"	23 19	24 19	24 21	20 24	20 26	Rhodium 18 19	24 19	137 148	Nickel 135 131	120 131
P20S1R2	Rhodium .000020" to .000030" over Silver .0001"	Microsection Only				31 38	Rhodium 34 41	48 38	131 138	Silver 136 129	138 141
S20S1R2	Rhodium .000020" to .000030" over Silver .0001"	Microsection Only				33 37	Rhodium 41 38	40 33	115 122	Silver 128 167	174 166

TABLE 1

THICKNESS MEASUREMENTS OF PLATED CONTACTS

LOT	PLATING REQUIREMENTS	* BETA SCOPE (Thickness X 10^{-6} Inches)				MICROSECTION (Thickness X 10^{-6} Inches)					
P16S1G3	Gold .000030" over Silver .0001" **	Silver Only	150 148	133 162	148 -	39 43	Gold 33 29	32 37	145 158	Silver 156 153	162 155
S16S1G3	Gold .000030" over Silver .0001" **	Silver Only	165 132	138 143	142 -	25 32	Gold 26 28	29 26	119 142	Silver 149 133	137 137
P16S1G1	Gold .0001" over Silver .0001"	Microsection Only				150 152	Gold 157 137	149 147	142 123	Silver 132 132	150 163
S16S1G1	Gold .0001" over Silver .0001"	Microsection Only				116 106	Gold 108 111	120 117	118 138	Silver 131 151	113 109
P16S2G5	Gold .000050" over Silver .0002" **	Silver Only	222 242	328 252	295 -	62 64	Gold 71 56	68 69	397 394	Silver 374 479	465 453
S16S2G5	Gold .000050" over Silver .0002" **	Silver Only	270 265	255 290	268 -	45 50	Gold 53 43	56 54	352 373	Silver 466 339	460 363
P16N1G3	Gold .000030" over Nickel .0001"	32 36	33 27	32 34	23 32	28 25	Gold 26 28	26 26	130 153	Nickel 139 161	133 160
S16N1G3	Gold .000030" over Nickel .0001"	32 33	31 25	26 28	38 37	20 34	Gold 29 30	33 27	136 133	Nickel 111 137	134 131
P16N1G1	Gold .0001" over Nickel .0001"	101 110	99 110	111 109	92 107	104 101	Gold 112 102	98 105	147 154	Nickel 149 151	127 144

TABLE 1

THICKNESS MEASUREMENTS OF PLATED CONTACTS

		Thickness X 10^{-6} Inches									
LOT	PLATING REQUIREMENTS	* BETA SCOPE				MICROSECTION					
S16N1G1	Gold .0001" over Nickel .0001"	102 116	118 118	127 97	105 103	101 111	Gold 123 126	119 109	118 130	Nickel 152 139	145 147
P16C1G3	Gold .000030" over Copper .0001"	42 34	30 28	42 34	38 28	35 23	Gold 28 21	33 22	122 119	Copper 134 119	115 124
S16C1G3	Gold .000030" over Copper .0001"	32 38	33 33	26 38	32 34	30 31	Gold 20 29	37 23	115 120	Copper 126 110	108 109
P16C1G1	Gold .0001" over Copper .0001"	105 102	107 103	110 116	105 102	119 122	Gold 129 95	99 109	45 48	Copper 43 49	54 40
S16C1G1	Gold .0001" over Copper .0001"	100 110	102 108	114 113	113 103	102 118	Gold 101 108	104 88	116 115	Copper 129 111	113 116
P16N1R2	Rhodium .000020" to .000030" over Nickel .0001"	42 31	40 41	44 47	41 34	30 27	Rhodium 33 27	31 23	142 148	Nickel 145 138	144 141
S16N1R2	Rhodium .000020" to .000030" over Nickel .0001"	21 20	24 33	32 23	23 29	22 20	Rhodium 24 20	20 23	165 162	Nickel 167 134	142 140
P16S1R2	Rhodium .000020" to .000030" over Nickel .0001"	Microsection Only				36 40	Rhodium 33 33	37 37	160 133	Silver 150 167	149 159
S16S1R2	Rhodium .000020" to .000030" over Silver .0001"	Microsection Only				36 33	Rhodium 43 34	38 44	145 151	Silver 152 134	130 136

TABLE 2

SUMMARY OF CONTACT RESISTANCE MEASUREMENTS
TAKEN AT FT. TILDEN, N.Y. EXPOSURE SITE
SIZE #20 MIL-C-26636 CONTRACTS FOLLOWING
100 INSERTION AND WITHDRAWAL CYCLES

Plating Description	Date	1/11/66	2/8/66	3/10/66	4/11/66	5/12/66	6/9/66	8/11/66	10/14/66	12/15/66	2/15/67	4/20/67	5/18/67	6/21/67	7/31/67	8/30/67	9/27/67	10/27/67	11/29/67
	Temp.	25°F	37°F	45°F	54°F	49°F	68°F	75°F	59°F	40°F	51°F	58°F	62°F	77°F	78°F	75°F	70°F	53°F	33°F
		RESISTANCE IN MILLIOHMS																	
Gold .000030"	Max.	0.56	0.56	0.57	0.56	0.56	0.58	0.58	0.58	0.58	0.56	0.56	0.56	0.58	0.58	0.58	0.58	0.56	0.54
over	Min.	0.35	0.42	0.42	0.42	0.42	0.44	0.44	0.45	0.45	0.43	0.43	0.43	0.44	0.45	0.44	0.44	0.43	0.41
Silver .000100"	Avg.	0.42	0.48	0.49	0.48	0.48	0.51	0.51	0.51	0.51	0.49	0.49	0.49	0.51	0.51	0.51	0.51	0.50	0.48
Gold .000100"	Max.	0.58	0.66	0.69	0.62	0.75	0.72	0.72	0.72	0.71	0.69	0.67	0.69	0.69	0.72	0.72	0.72	0.69	0.67
over	Min.	0.38	0.45	0.46	0.44	0.45	0.48	0.47	0.47	0.47	0.47	0.46	0.47	0.48	0.49	0.49	0.49	0.46	0.45
Silver .000100"	Avg.	0.44	0.51	0.52	0.50	0.53	0.54	0.54	0.54	0.53	0.52	0.52	0.52	0.53	0.54	0.54	0.54	0.52	0.51
Gold .000050"	Max.	0.48	0.55	0.56	0.57	0.60	0.60	0.61	0.60	0.60	0.57	0.56	0.58	0.59	0.60	0.60	0.60	0.58	0.56
over	Min.	0.36	0.41	0.42	0.42	0.43	0.43	0.44	0.45	0.45	0.44	0.44	0.44	0.45	0.44	0.45	0.46	0.44	0.42
Silver .000200"	Avg.	0.41	0.46	0.47	0.48	0.48	0.49	0.50	0.50	0.50	0.48	0.48	0.49	0.49	0.50	0.50	0.50	0.48	0.47
Gold .000030"	Max.	0.65	0.73	0.75	0.74	0.77	0.78	0.77	0.77	0.77	0.74	0.76	0.83	0.85	0.88	0.92	0.92	0.89	0.86
over	Min.	0.41	0.47	0.48	0.49	0.48	0.50	0.50	0.50	0.50	0.48	0.48	0.49	0.50	0.51	0.50	0.50	0.48	0.47
Nickel .000100"	Avg.	0.53	0.60	0.62	0.61	0.63	0.64	0.64	0.64	0.63	0.61	0.62	0.63	0.65	0.66	0.66	0.66	0.64	0.63
Gold .000100"	Max.	0.62	0.74	0.74	0.72	0.72	0.74	0.75	0.74	0.74	0.72	0.72	0.73	0.74	0.76	0.76	0.76	0.74	0.74
over	Min.	0.41	0.47	0.48	0.48	0.48	0.50	0.50	0.50	0.50	0.49	0.48	0.50	0.51	0.52	0.52	0.52	0.53	0.53
Nickel .000100"	Avg.	0.48	0.56	0.57	0.57	0.57	0.59	0.60	0.59	0.59	0.58	0.58	0.59	0.62	0.65	0.65	0.65	0.64	0.62
Gold .000030"	Max.	0.54	0.63	0.65	0.65	0.65	0.67	0.67	0.68	0.67	0.65	0.65	0.66	0.67	0.68	0.68	0.68	0.65	0.63
over	Min.	0.37	0.42	0.43	0.43	0.42	0.45	0.46	0.45	0.45	0.43	0.44	0.44	0.45	0.46	0.45	0.45	0.44	0.42
Copper .000100"	Avg.	0.46	0.53	0.54	0.55	0.56	0.57	0.58	0.57	0.56	0.55	0.55	0.56	0.57	0.58	0.58	0.58	0.56	0.53
Gold .000100"	Max.	0.56	0.64	0.66	0.68	0.73	0.70	0.70	0.70	0.70	0.67	0.66	0.67	0.69	0.70	0.70	0.70	0.67	0.64
over	Min.	0.44	0.51	0.52	0.50	0.52	0.54	0.55	0.55	0.54	0.52	0.53	0.53	0.54	0.55	0.54	0.54	0.52	0.50
Copper .000100"	Avg.	0.49	0.55	0.57	0.56	0.58	0.59	0.59	0.59	0.59	0.57	0.57	0.57	0.59	0.60	0.59	0.59	0.57	0.55
Rhodium .000020"	Max.	1.50	1.60	1.65	1.60	1.60	1.66	1.67	1.69	1.70	1.65	1.70	1.72	1.75	1.78	1.77	1.78	1.75	1.72
over	Min.	0.70	0.76	0.75	0.74	0.74	0.75	0.76	0.76	0.76	0.75	0.75	0.76	0.79	0.81	0.81	0.81	0.79	0.77
Nickel .000100"	Avg.	1.01	1.08	1.08	1.08	1.08	1.11	1.12	1.13	1.13	1.11	1.13	1.13	1.15	1.17	1.18	1.18	1.16	1.14
	Std.Dev.	0.28	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.31
Rhodium .000020"	Max.	1.10	1.15	1.20	1.15	1.16	1.16	1.17	1.14	1.14	1.17	1.18	1.16	1.14	1.15	1.25	1.50	2.03	2.35
over	Min.	0.48	0.53	0.55	0.54	0.55	0.57	0.57	0.58	0.56	0.56	0.56	0.56	0.58	0.58	0.60	0.60	0.58	0.57
Silver .000100"	Avg.	0.65	0.70	0.72	0.71	0.72	0.73	0.73	0.73	0.71	0.72	0.71	0.71	0.72	0.73	0.74	0.74	0.85	0.88
	Std.Dev.	0.08	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.49

TABLE 2

SUMMARY OF CONTACT RESISTANCE MEASUREMENTS
TAKEN AT FT. TILDEN, N.Y. EXPOSURE SITE
SIZE #20 MIL-C-26636 CONTACTS FOLLOWING
INITIAL MATING

Plating Description	Date / Temp.	1/11/66 25°F	2/8/66 37°F	3/10/66 45°F	4/11/66 54°F	5/12/66 49°F	6/9/66 68°F	8/11/66 75°F	10/14/66 59°F	12/15/66 40°F	2/15/67 51°F	4/20/67 58°F	5/18/67 62°F	6/21/67 77°F	7/31/67 78°F	8/30/67 75°F	9/27/67 70°F	10/27/67 53°F	11/29/67 33°F
		RESISTANCE IN MILLIOHMS																	
Gold .000030"	Max.	0.51	0.57	0.58	0.58	0.65	0.64	0.64	0.63	0.60	0.60	0.59	0.61	0.62	0.63	0.64	0.64	0.61	0.58
over	Min.	0.38	0.42	0.44	0.43	0.44	0.46	0.46	0.47	0.45	0.44	0.45	0.44	0.45	0.45	0.45	0.45	0.44	0.42
Silver .000100"	Avg.	0.44	0.50	0.51	0.51	0.52	0.54	0.54	0.54	0.52	0.52	0.52	0.52	0.53	0.54	0.54	0.54	0.53	0.51
Gold .000100"	Max.	0.60	0.66	0.67	0.66	0.68	0.67	0.67	0.68	0.64	0.64	0.65	0.65	0.67	0.67	0.67	0.67	0.65	0.62
over	Min.	0.39	0.43	0.45	0.44	0.43	0.45	0.46	0.48	0.45	0.44	0.45	0.45	0.46	0.46	0.46	0.46	0.44	0.42
Silver .000100"	Avg.	0.47	0.52	0.53	0.53	0.53	0.55	0.55	0.56	0.54	0.53	0.53	0.54	0.55	0.56	0.56	0.55	0.54	0.52
Gold .000050"	Max.	0.48	0.54	0.56	0.57	0.62	0.60	0.61	0.61	0.58	0.57	0.57	0.58	0.60	0.61	0.61	0.60	0.58	0.56
over	Min.	0.36	0.40	0.41	0.42	0.41	0.42	0.42	0.44	0.43	0.42	0.41	0.42	0.43	0.43	0.44	0.44	0.44	0.43
Silver .000200"	Avg.	0.43	0.48	0.49	0.49	0.50	0.51	0.52	0.52	0.50	0.50	0.50	0.50	0.51	0.52	0.52	0.52	0.52	0.50
Gold .000030"	Max.	0.67	0.75	0.78	0.78	0.80	0.81	0.81	0.81	0.77	0.79	0.80	0.80	0.83	0.86	0.87	0.88	0.84	0.82
over	Min.	0.48	0.53	0.55	0.54	0.54	0.56	0.56	0.57	0.55	0.55	0.56	0.56	0.56	0.58	0.58	0.58	0.55	0.54
Nickel .000100"	Avg.	0.56	0.61	0.63	0.63	0.64	0.65	0.65	0.65	0.63	0.64	0.65	0.65	0.66	0.68	0.68	0.69	0.67	0.65
Gold .000100"	Max.	0.64	0.70	0.72	0.71	0.70	0.74	0.74	0.74	0.72	0.72	0.73	0.73	0.74	0.76	0.77	0.77	0.73	0.71
over	Min.	0.44	0.49	0.50	0.49	0.50	0.52	0.52	0.52	0.51	0.51	0.51	0.51	0.52	0.53	0.52	0.52	0.51	0.49
Nickel .000100"	Avg.	0.53	0.58	0.60	0.59	0.60	0.62	0.62	0.63	0.61	0.61	0.62	0.63	0.65	0.66	0.67	0.67	0.65	0.64
Gold .000030"	Max.	0.53	0.60	0.62	0.62	0.65	0.65	0.65	0.65	0.62	0.61	0.62	0.63	0.64	0.65	0.65	0.65	0.62	0.60
over	Min.	0.38	0.41	0.42	0.42	0.43	0.44	0.45	0.45	0.44	0.43	0.43	0.43	0.44	0.45	0.45	0.45	0.43	0.41
Copper .000100"	Avg.	0.45	0.50	0.51	0.51	0.52	0.54	0.54	0.54	0.52	0.51	0.51	0.52	0.53	0.54	0.54	0.54	0.51	0.49
Gold .000100"	Max.	0.66	0.74	0.74	0.74	0.75	0.74	0.73	0.73	0.69	0.69	0.69	0.68	0.69	0.72	0.73	0.73	0.70	0.69
over	Min.	0.40	0.44	0.46	0.45	0.45	0.47	0.47	0.47	0.46	0.45	0.45	0.45	0.46	0.48	0.47	0.47	0.45	0.44
Copper .000100"	Avg.	0.48	0.53	0.53	0.53	0.53	0.55	0.56	0.55	0.54	0.53	0.53	0.53	0.53	0.55	0.56	0.55	0.53	0.52
Rhodium .000020"	Max.	1.10	1.10	1.10	1.10	1.10	1.12	1.14	1.17	1.18	1.15	1.15	1.17	1.20	1.20	1.20	1.20	1.15	1.13
over	Min.	0.63	0.69	0.72	0.70	0.70	0.72	0.72	0.73	0.72	0.72	0.72	0.73	0.78	0.82	0.81	0.81	0.78	0.75
Nickel .000100"	Avg.	0.78	0.86	0.88	0.87	0.88	0.90	0.90	0.91	0.90	0.89	0.90	0.91	0.93	0.95	0.96	0.96	0.93	0.91
	Std.Dev.	0.01	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.13
Rhodium .000020"	Max.	0.71	0.77	0.79	0.74	0.82	0.80	0.80	0.80	0.77	0.77	0.76	0.78	0.78	0.82	0.86	0.88	0.85	0.84
over	Min.	0.50	0.54	0.55	0.54	0.55	0.57	0.57	0.57	0.55	0.55	0.54	0.56	0.56	0.57	0.58	0.59	0.57	0.56
Silver .000100"	Avg.	0.63	0.69	0.70	0.69	0.70	0.71	0.71	0.71	0.69	0.69	0.69	0.70	0.71	0.74	0.76	0.76	0.75	0.72
	Std.Dev.	0.73	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.09

TABLE 2

SUMMARY OF CONTACT RESISTANCE MEASUREMENTS
TAKEN AT FT. TILDEN, N.Y. EXPOSURE SITE
SIZE #16 MIL-C-26636 CONTACTS FOLLOWING
100 INSERTION AND WITHDRAWAL CYCLES

Plating Description	Date Temp.	1/11/66 25°F	2/8/66 37°F	3/10/66 45°F	4/11/66 54°F	5/12/66 49°F	6/9/66 68°F	8/11/66 75°F	10/14/66 59°F	12/15/66 40°F	2/15/67 51°F	4/20/67 58°F	5/18/67 62°F	6/21/67 77°F	7/31/67 78°F	8/30/67 75°F	9/27/67 70°F	10/27/67 53°F	11/29/67 33°F
		RESISTANCE IN MILLIOHMS																	
Gold .000030"	Max.	0.41	0.47	0.48	0.46	0.45	0.52	0.53	0.52	0.50	0.50	0.50	0.50	0.51	0.52	0.52	0.51	0.50	0.48
over	Min.	0.27	0.30	0.32	0.31	0.31	0.34	0.34	0.33	0.34	0.32	0.32	0.32	0.33	0.33	0.33	0.33	0.32	0.31
Silver .000100"	Avg.	0.33	0.38	0.39	0.38	0.38	0.42	0.42	0.42	0.41	0.40	0.40	0.40	0.41	0.41	0.41	0.41	0.40	0.39
Gold .000100"	Max.	0.47	0.54	0.56	0.57	0.57	0.59	0.61	0.60	0.57	0.57	0.55	0.56	0.59	0.60	0.60	0.60	0.57	0.54
over	Min.	0.25	0.28	0.29	0.30	0.30	0.32	0.33	0.32	0.32	0.30	0.29	0.30	0.31	0.31	0.31	0.31	0.30	0.29
Silver .000100"	Avg.	0.35	0.40	0.41	0.41	0.42	0.44	0.44	0.44	0.43	0.42	0.41	0.41	0.43	0.43	0.43	0.43	0.42	0.40
Gold .000050"	Max.	0.41	0.46	0.48	0.45	0.48	0.51	0.52	0.52	0.50	0.49	0.48	0.49	0.50	0.51	0.51	0.51	0.51	0.50
over	Min.	0.23	0.26	0.26	0.27	0.27	0.29	0.30	0.29	0.29	0.28	0.28	0.28	0.28	0.29	0.28	0.28	0.27	0.24
Silver .000200"	Avg.	0.30	0.34	0.35	0.35	0.36	0.38	0.39	0.38	0.37	0.36	0.36	0.36	0.37	0.38	0.37	0.37	0.37	0.36
Gold .000030"	Max.	0.48	0.54	0.56	0.55	0.55	0.57	0.58	0.58	0.56	0.56	0.56	0.56	0.58	0.58	0.59	0.59	0.57	0.55
over	Min.	0.27	0.30	0.31	0.31	0.32	0.33	0.34	0.33	0.33	0.32	0.32	0.32	0.32	0.33	0.33	0.33	0.32	0.32
Nickel .000100"	Avg.	0.37	0.42	0.43	0.43	0.44	0.45	0.46	0.46	0.44	0.44	0.43	0.44	0.45	0.46	0.46	0.46	0.44	0.43
Gold .000100"	Max.	0.56	0.65	0.66	0.62	0.66	0.67	0.67	0.67	0.64	0.64	0.64	0.65	0.66	0.67	0.67	0.67	0.65	0.63
over	Min.	0.24	0.26	0.27	0.27	0.28	0.30	0.30	0.30	0.30	0.28	0.28	0.28	0.29	0.29	0.30	0.30	0.29	0.29
Nickel .000100"	Avg.	0.39	0.44	0.45	0.44	0.45	0.47	0.47	0.47	0.46	0.45	0.45	0.45	0.46	0.47	0.47	0.47	0.46	0.45
Gold .000030"	Max.	0.39	0.43	0.44	0.44	0.45	0.48	0.49	0.49	0.46	0.45	0.44	0.45	0.47	0.48	0.48	0.48	0.46	0.43
over	Min.	0.24	0.27	0.28	0.28	0.28	0.31	0.31	0.31	0.31	0.29	0.29	0.29	0.30	0.30	0.30	0.31	0.30	0.29
Copper .000100"	Avg.	0.32	0.35	0.36	0.36	0.36	0.39	0.39	0.39	0.38	0.37	0.37	0.37	0.38	0.39	0.39	0.39	0.38	0.36
Gold .000100"	Max.	0.44	0.47	0.48	0.48	0.48	0.52	0.54	0.53	0.50	0.50	0.50	0.50	0.52	0.53	0.52	0.52	0.50	0.48
over	Min.	0.31	0.34	0.34	0.34	0.34	0.37	0.37	0.37	0.36	0.35	0.35	0.35	0.35	0.36	0.36	0.36	0.35	0.34
Copper .000100"	Avg.	0.37	0.40	0.41	0.41	0.41	0.44	0.44	0.44	0.42	0.42	0.41	0.42	0.43	0.44	0.43	0.43	0.42	0.40
Rhodium.000020"	Max.	1.10	1.20	1.20	1.20	1.20	1.20	1.20	1.23	1.25	1.20	1.20	1.20	1.20	1.22	1.22	1.22	1.20	1.20
over	Min.	0.56	0.62	0.63	0.62	0.64	0.64	0.64	0.65	0.63	0.63	0.63	0.63	0.64	0.65	0.65	0.65	0.63	0.62
Nickel .000100"	Avg.	0.78	0.85	0.86	0.86	0.87	0.87	0.87	0.88	0.86	0.86	0.85	0.86	0.87	0.89	0.88	0.88	0.86	0.85
	Std.Dev.	0.02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.02
Rhodium.000020"	Max.	0.58	0.63	0.64	0.63	0.64	0.63	0.63	0.64	0.61	0.61	0.60	0.60	0.60	0.60	0.60	0.60	0.58	0.57
over	Min.	0.28	0.31	0.32	0.32	0.33	0.33	0.33	0.34	0.35	0.33	0.33	0.33	0.34	0.34	0.34	0.34	0.34	0.33
Silver .000100"	Avg.	0.42	0.46	0.47	0.47	0.48	0.50	0.50	0.49	0.49	0.48	0.47	0.48	0.49	0.49	0.49	0.49	0.48	0.47
	Std.Dev.	0.10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.09

TABLE 2

SUMMARY OF CONTACT RESISTANCE MEASUREMENTS
TAKEN AT FT. TILDEN, N.Y. EXPOSURE SITE
SIZE #16 MIL-C-26636 CONTACTS FOLLOWING
INITIAL MATING

Plating Description	Date / Temp.	1/11/66 25°F	2/8/66 37°F	3/10/66 45°F	4/11/66 54°F	5/12/66 49°F	6/9/66 68°F	8/11/66 75°F	10/14/66 59°F	12/15/66 40°F	2/15/67 51°F	4/20/67 58°F	5/18/67 62°F	6/21/67 77°F	7/31/67 78°F	8/30/67 75°F	9/27/67 70°F	10/27/67 53°F	11/29/67 33°F
	RESISTANCE IN MILLIOHMS																		
Gold .000030"	Max.	0.46	0.50	0.51	0.52	0.52	0.56	0.56	0.56	0.53	0.52	0.51	0.53	0.55	0.56	0.56	0.56	0.53	0.50
over	Min.	0.24	0.25	0.26	0.26	0.26	0.28	0.29	0.29	0.28	0.26	0.25	0.26	0.26	0.27	0.26	0.26	0.25	0.23
Silver .000100"	Avg.	0.32	0.34	0.35	0.35	0.36	0.38	0.38	0.38	0.37	0.36	0.35	0.36	0.37	0.37	0.37	0.37	0.36	0.34
Gold .000100"	Max.	0.42	0.46	0.47	0.46	0.47	0.48	0.48	0.48	0.47	0.46	0.46	0.47	0.47	0.48	0.48	0.48	0.46	0.45
over	Min.	0.29	0.31	0.32	0.32	0.33	0.34	0.34	0.34	0.34	0.32	0.32	0.33	0.33	0.33	0.33	0.33	0.32	0.31
Silver .000100"	Avg.	0.36	0.38	0.39	0.39	0.40	0.42	0.42	0.42	0.41	0.40	0.40	0.40	0.41	0.42	0.41	0.41	0.40	0.39
Gold .000050"	Max.	0.41	0.44	0.45	0.45	0.45	0.49	0.50	0.49	0.47	0.46	0.45	0.46	0.48	0.49	0.48	0.48	0.46	0.44
over	Min.	0.27	0.28	0.29	0.29	0.30	0.32	0.32	0.32	0.32	0.30	0.30	0.30	0.31	0.31	0.31	0.31	0.30	0.29
Silver .000200"	Avg.	0.33	0.35	0.36	0.36	0.37	0.39	0.39	0.39	0.38	0.37	0.36	0.37	0.38	0.38	0.38	0.38	0.36	0.35
Gold .000030"	Max.	0.44	0.50	0.50	0.50	0.53	0.53	0.53	0.53	0.51	0.51	0.50	0.51	0.52	0.53	0.53	0.54	0.51	0.49
over	Min.	0.30	0.32	0.33	0.32	0.33	0.35	0.35	0.35	0.34	0.33	0.33	0.33	0.33	0.34	0.34	0.34	0.33	0.32
Nickel .000100"	Avg.	0.37	0.40	0.41	0.40	0.42	0.43	0.44	0.44	0.42	0.41	0.41	0.42	0.42	0.43	0.43	0.43	0.41	0.40
Gold .000100"	Max.	0.51	0.56	0.57	0.57	0.58	0.59	0.60	0.59	0.57	0.57	0.56	0.57	0.58	0.59	0.58	0.58	0.57	0.54
over	Min.	0.25	0.26	0.27	0.27	0.26	0.29	0.29	0.30	0.29	0.28	0.28	0.28	0.29	0.29	0.29	0.29	0.28	0.27
Nickel .000100"	Avg.	0.36	0.39	0.39	0.40	0.40	0.42	0.42	0.42	0.41	0.40	0.40	0.40	0.41	0.42	0.42	0.42	0.41	0.39
Gold .000030"	Max.	0.58	0.58	0.58	0.57	0.56	0.56	0.57	0.56	0.54	0.53	0.53	0.54	0.54	0.55	0.55	0.55	0.52	0.52
over	Min.	0.27	0.29	0.29	0.30	0.29	0.32	0.32	0.32	0.32	0.30	0.30	0.30	0.31	0.31	0.31	0.31	0.30	0.29
Copper .000100"	Avg.	0.39	0.39	0.39	0.39	0.39	0.41	0.41	0.41	0.40	0.39	0.38	0.39	0.40	0.40	0.40	0.40	0.38	0.37
Gold .000100"	Max.	0.40	0.43	0.44	0.44	0.50	0.48	0.49	0.49	0.46	0.45	0.44	0.45	0.47	0.47	0.47	0.47	0.45	0.43
over	Min.	0.32	0.34	0.35	0.34	0.35	0.38	0.37	0.37	0.37	0.36	0.36	0.36	0.36	0.37	0.37	0.37	0.35	0.35
Copper .000100"	Avg.	0.36	0.39	0.40	0.40	0.41	0.42	0.42	0.42	0.41	0.41	0.40	0.40	0.41	0.42	0.42	0.42	0.41	0.40
Rhodium .000020"	Max.	0.96	1.00	1.00	1.00	1.00	1.02	1.02	1.03	1.05	1.00	1.00	1.00	1.00	1.03	1.03	1.03	1.00	0.97
over	Min.	0.49	0.54	0.54	0.54	0.55	0.55	0.56	0.56	0.54	0.54	0.54	0.54	0.55	0.55	0.55	0.55	0.52	0.51
Nickel .000100"	Avg.	0.60	0.65	0.66	0.65	0.66	0.67	0.67	0.67	0.65	0.65	0.65	0.65	0.66	0.67	0.67	0.67	0.64	0.63
	Std.Dev.	0.14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.13
Rhodium .000020"	Max.	0.63	0.67	0.68	0.68	0.70	0.70	0.70	0.70	0.67	0.67	0.66	0.67	0.68	0.69	0.68	0.68	0.64	0.62
over	Min.	0.37	0.37	0.38	0.38	0.40	0.41	0.42	0.42	0.40	0.40	0.39	0.39	0.40	0.42	0.43	0.43	0.41	0.40
Silver .000100"	Avg.	0.46	0.49	0.50	0.50	0.51	0.52	0.52	0.52	0.50	0.50	0.50	0.50	0.51	0.51	0.52	0.52	0.50	0.48
	Std.Dev.	0.08	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.08

TABLE 3

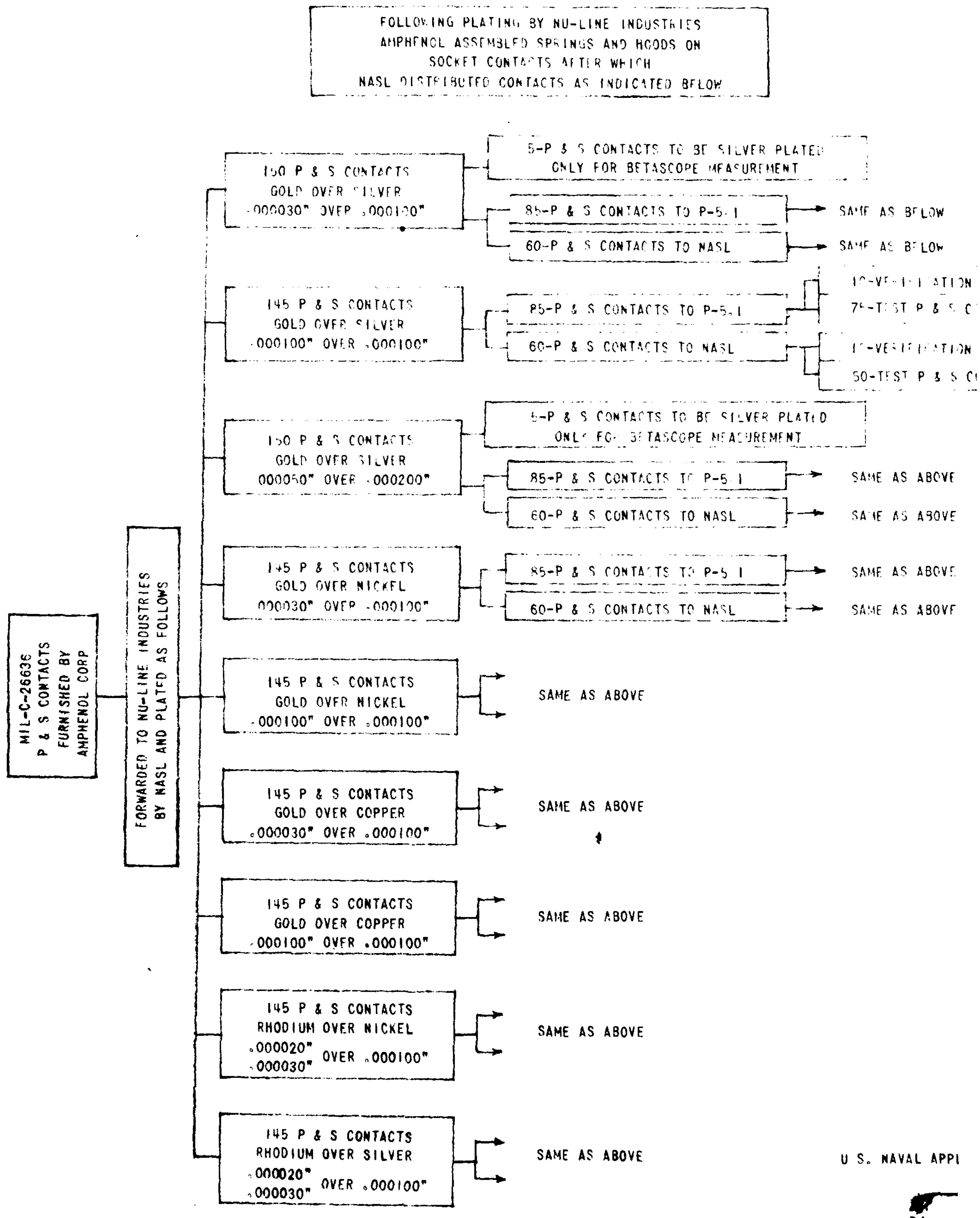
SUMMARY OF CONTACT RESISTANCE MEASUREMENTS
TAKEN AT NASL SALT SPRAY EXPOSURE SITE
SIZE #20 MIL-C-26636 CONTACTS FOLLOWING
100 INSERTION AND WITHDRAWAL CYCLES

Plating Description	Time (hrs) / Temp.	0	224	400	624	800	1008	1232	1408	1632	1808	2032	2192	2416	2592	2816	3040	3216	3440	3616	3792	4000
	Temp.	80°F	80°F	80°F	80°F	79°F	81°F	83°F	80°F	80°F	82°F	81°F	81°F	82°F	81°F	82°F	81°F	82°F	82°F	84°F	85°F	82°F
RESISTANCE IN MILLIOHMS																						
Gold .000030"	Max.	0.70	0.66	0.76	0.80	0.84	0.85	0.90	0.89	0.90	0.90	0.90	0.90	0.90	0.90	0.92	0.90	0.90	0.90	0.90	0.90	0.90
over	Min.	0.50	0.48	0.50	0.50	0.50	0.50	0.49	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.51	0.51	0.51	0.51	0.51	0.51	0.51
Silver .000100"	Avg.	0.61	0.55	0.58	0.59	0.60	0.59	0.60	0.60	0.62	0.63	0.63	0.63	0.62	0.63	0.64	0.63	0.64	0.64	0.64	0.64	0.64
Gold .000100"	Max.	0.61	0.60	0.61	0.62	0.62	0.62	0.64	0.63	0.80	0.76	0.76	0.75	0.75	1.25	1.25	1.15	1.15	1.10	1.10	1.10	1.10
over	Min.	0.41	0.40	0.41	0.44	0.45	0.43	0.44	0.44	0.44	0.43	0.43	0.43	0.43	0.43	0.44	0.43	0.44	0.43	0.44	0.44	0.44
Silver .000100"	Avg.	0.51	0.51	0.52	0.53	0.54	0.52	0.53	0.52	0.56	0.54	0.54	0.54	0.54	0.61	0.61	0.60	0.60	0.59	0.60	0.60	0.59
Gold .000050"	Max.	0.60	0.58	0.60	0.60	0.60	0.58	0.61	0.60	0.63	0.62	0.62	0.61	0.61	0.62	0.62	0.62	0.63	0.63	0.63	0.64	0.63
over	Min.	0.44	0.42	0.42	0.43	0.44	0.42	0.44	0.42	0.46	0.45	0.44	0.44	0.44	0.44	0.44	0.43	0.44	0.43	0.44	0.44	0.44
Silver .000200"	Avg.	0.52	0.50	0.50	0.51	0.52	0.50	0.52	0.51	0.54	0.53	0.53	0.53	0.53	0.54	0.54	0.53	0.54	0.54	0.54	0.55	0.54
Gold .000030"	Max.	1.25	1.70	21.50	30.00	34.00	32.00	35.00	38.00	42.00	44.00	105.00	105.00	115.00	122.00	150.00	155.00	160.00	175.00	540.00	650.00	695.00
over	Min.	0.52	0.60	0.62	0.63	0.64	0.65	0.67	0.73	1.30	2.00	8.20	14.50	18.00	24.00	26.00	28.00	31.00	41.00	45.00	47.00	48.00
Nickel .000100"	Avg.	0.67	0.82	2.97	4.05	5.08	5.72	8.33	10.68	15.51	20.43	32.12	35.30	47.65	56.10	63.70	73.50	79.60	88.00	141.30	173.60	211.60
	Std.Dev.	0.21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	178.88
Gold .000100"	Max.	0.77	0.83	1.86	4.70	6.00	7.20	9.30	12.50	22.00	24.00	25.00	25.50	30.00	30.00	31.00	31.00	29.00	35.00	38.00	38.00	38.00
over	Min.	0.57	0.56	0.59	0.60	0.62	0.61	0.62	0.62	0.65	0.67	0.68	0.70	0.70	0.70	0.70	0.75	0.76	0.76	0.76	0.77	0.77
Nickel .000100"	Avg.	0.66	0.68	0.86	1.20	1.35	1.53	2.29	2.80	5.01	5.23	6.29	7.40	8.94	8.95	9.33	9.53	9.96	13.20	13.62	13.85	14.63
	Std.Dev.	0.02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12.24
Gold .000030"	Max.	0.75	0.75	0.77	1.80	1.75	1.65	1.60	1.60	1.60	1.60	1.65	1.65	1.75	1.55	1.60	1.60	1.55	1.55	1.55	1.55	1.55
over	Min.	0.55	0.54	0.58	0.57	0.58	0.55	0.58	0.62	0.61	0.60	0.60	0.59	0.59	0.58	0.60	0.59	0.60	0.60	0.60	0.60	0.60
Copper .000100"	Avg.	0.62	0.62	0.64	0.78	0.78	0.75	0.76	0.76	0.78	0.78	0.78	0.78	0.79	0.77	0.78	0.78	0.77	0.77	0.78	0.78	0.78
Gold .000100"	Max.	0.80	0.78	0.77	0.79	0.80	0.78	0.79	0.79	0.79	0.80	0.78	0.78	0.79	0.78	0.80	0.78	0.78	0.78	0.78	0.78	0.78
over	Min.	0.51	0.52	0.53	0.53	0.54	0.52	0.54	0.53	0.54	0.54	0.53	0.53	0.53	0.54	0.54	0.54	0.54	0.53	0.54	0.54	0.54
Copper .000100"	Avg.	0.63	0.62	0.63	0.63	0.64	0.63	0.64	0.63	0.65	0.65	0.64	0.64	0.64	0.64	0.65	0.64	0.64	0.64	0.64	0.64	0.64
Rhodium .000020"	Max.	2.20	4.00	39.00	67.00	76.00	80.00	92.00	96.00	122.00	400.00	460.00	500.00	570.00	620.00	690.00	750.00	920.00	965.00	1040.00	1060.00	1140.00
over	Min.	1.05	1.05	1.10	1.30	1.35	1.35	1.70	3.05	17.00	22.00	26.50	30.00	36.00	36.00	36.00	36.00	38.00	39.00	39.00	40.00	40.00
Nickel .000100"	Avg.	1.39	1.81	9.27	17.19	22.44	29.36	38.83	44.62	74.90	112.00	129.45	161.45	200.80	236.60	362.60	517.60	569.00	610.90	633.60	666.20	708.20
	Std.Dev.	0.33	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	370.03
Rhodium .000020"	Max.	0.89	1.25	1.50	1.50	1.55	1.50	1.50	1.50	1.40	1.45	1.45	1.40	1.45	1.45	1.50	1.43	1.40	1.40	1.40	1.40	1.40
over	Min.	0.58	0.65	0.62	0.62	0.62	0.61	0.61	0.61	0.63	0.63	0.63	0.63	0.64	0.63	0.64	0.63	0.64	0.63	0.64	0.64	0.64
Silver .000100"	Avg.	0.72	0.78	0.80	0.80	0.82	0.80	0.80	0.80	0.82	0.82	0.83	0.82	0.82	0.82	0.83	0.82	0.83	0.82	0.83	0.83	0.82
	Std.Dev.	0.09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.23

TABLE 3

SUMMARY OF CONTACT RESISTANCE MEASUREMENTS
TAKEN AT NASL SALT SPRAY EXPOSURE SITE
SIZE #20 MIL-C-26636 CONTACTS FOLLOWING
INITIAL MATING

Plating Description	Time (hrs)	0	224	400	624	800	1008	1232	1408	1632	1808	2032	2192	2416	2592	2816	3040	3216	3440	3616	3792	4000
	Temp.	80°F	80°F	80°F	80°F	79°F	81°F	83°F	80°F	80°F	82°F	81°F	81°F	82°F	81°F	82°F	81°F	82°F	82°F	84°F	85°F	85°F
RESISTANCE IN MILLIOHMS																						
Gold .000030"	Max.	0.74	0.73	0.74	0.72	0.73	0.72	0.72	0.71	0.72	0.72	0.72	0.71	0.71	0.71	0.71	0.71	0.73	0.74	0.73	0.74	0.73
over	Min.	0.54	0.54	0.55	0.55	0.56	0.54	0.54	0.54	0.56	0.55	0.55	0.55	0.55	0.55	0.56	0.55	0.56	0.55	0.55	0.56	0.56
Silver .000100"	Avg.	0.59	0.59	0.60	0.59	0.60	0.59	0.59	0.59	0.60	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.60	0.60	0.60	0.60	0.60
Gold .000100"	Max.	0.62	0.61	0.63	0.62	0.62	0.61	0.62	0.61	0.62	0.62	0.62	0.62	0.62	0.62	0.61	0.61	0.63	0.62	0.62	0.63	0.62
over	Min.	0.48	0.48	0.49	0.49	0.50	0.48	0.48	0.48	0.49	0.50	0.49	0.49	0.50	0.49	0.50	0.49	0.49	0.49	0.49	0.50	0.49
Silver .000100"	Avg.	0.55	0.55	0.56	0.56	0.56	0.55	0.55	0.55	0.56	0.56	0.56	0.56	0.56	0.56	0.57	0.56	0.56	0.56	0.56	0.57	0.56
Gold .000050"	Max.	0.69	0.68	0.70	0.68	0.68	0.67	0.67	0.67	0.68	0.68	0.67	0.67	0.67	0.72	0.72	0.72	0.74	0.74	0.74	0.74	0.74
over	Min.	0.50	0.48	0.50	0.50	0.50	0.49	0.50	0.50	0.50	0.51	0.50	0.50	0.50	0.50	0.51	0.50	0.50	0.50	0.50	0.50	0.50
Silver .000200"	Avg.	0.61	0.60	0.61	0.61	0.61	0.60	0.60	0.60	0.61	0.61	0.60	0.60	0.60	0.61	0.62	0.63	0.64	0.64	0.64	0.64	0.64
Gold .000030"	Max.	0.76	1.20	2.34	14.00	32.00	30.00	60.00	66.00	68.00	72.00	76.00	79.00	94.00	95.00	98.00	105.00	265.00	272.00	282.00	290.00	315.00
over	Min.	0.53	0.63	0.69	0.70	0.75	0.91	1.20	1.30	2.10	2.40	2.45	2.90	4.00	17.00	22.00	25.00	32.00	41.00	47.00	69.00	76.00
Nickel .000100"	Avg.	0.68	0.83	1.37	4.77	7.33	8.63	13.25	15.75	24.83	29.73	34.48	38.58	47.35	51.20	59.10	64.30	92.70	102.40	118.20	129.30	158.70
	Std.Dev.	0.08	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	88.85
Gold .000100"	Max.	0.77	0.93	1.10	3.70	12.50	10.00	17.50	19.50	20.00	36.00	44.00	81.00	82.00	84.00	62.00	56.00	42.00	42.20	43.00	43.00	44.00
over	Min.	0.58	0.62	0.64	0.64	0.64	0.63	0.64	0.68	0.70	0.70	0.76	0.76	0.76	0.80	0.88	0.88	0.88	0.88	0.89	0.89	0.88
Nickel .000100"	Avg.	0.69	0.73	0.83	1.57	2.90	3.33	4.41	6.37	7.05	9.82	11.65	15.81	19.38	20.18	18.04	17.70	15.89	15.96	18.14	17.82	19.13
	Std.Dev.	0.06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14.94
Gold .000030"	Max.	0.70	0.70	0.71	0.81	0.81	0.81	0.81	0.81	0.80	0.81	0.81	0.80	0.81	0.81	0.82	0.80	0.81	0.80	0.80	0.81	0.80
over	Min.	0.56	0.56	0.56	0.58	0.60	0.58	0.60	0.60	0.64	0.63	0.64	0.63	0.63	0.63	0.64	0.63	0.64	0.64	0.64	0.65	0.65
Copper .000100"	Avg.	0.63	0.63	0.64	0.66	0.67	0.66	0.67	0.67	0.68	0.68	0.68	0.68	0.68	0.68	0.69	0.68	0.69	0.68	0.68	0.69	0.68
Gold .000100"	Max.	0.80	0.77	0.79	0.77	0.77	0.76	0.76	0.75	0.77	0.75	0.77	0.75	0.75	0.75	0.76	0.75	0.77	0.77	0.77	0.78	0.77
over	Min.	0.51	0.50	0.52	0.51	0.52	0.51	0.53	0.53	0.56	0.56	0.55	0.55	0.55	0.55	0.56	0.56	0.56	0.56	0.57	0.57	0.57
Copper .000100"	Avg.	0.64	0.63	0.65	0.64	0.65	0.63	0.64	0.64	0.65	0.65	0.64	0.64	0.64	0.64	0.65	0.64	0.65	0.65	0.65	0.65	0.65
Rhodium.000020"	Max.	1.15	1.35	7.65	33.00	60.00	68.00	120.00	160.00	420.00	440.00	510.00	500.00	610.00	650.00	670.00	850.00	810.00	850.00	880.00	890.00	905.00
over	Min.	0.84	0.90	1.05	1.10	1.15	1.10	1.15	1.20	1.60	1.60	1.60	1.90	2.55	2.90	2.90	2.90	2.95	4.30	53.00	98.00	108.00
Nickel .000100"	Avg.	1.01	1.08	2.04	4.78	8.42	11.03	22.26	31.37	73.48	138.09	165.87	172.84	251.23	266.91	390.89	473.29	485.00	519.33	539.90	580.70	594.30
	Std.Dev.	0.12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	252.45
Rhodium.000020"	Max.	0.92	0.83	0.83	1.10	4.00	8.00	16.50	18.00	18.00	15.00	15.50	14.00	12.50	12.50	15.00	18.00	17.50	18.00	18.00	18.80	18.00
over	Min.	0.58	0.58	0.58	0.60	0.60	0.60	0.60	0.60	0.61	0.61	0.61	0.62	0.62	0.62	0.65	0.64	0.64	0.64	0.65	0.65	0.65
Silver .000100"	Avg.	0.75	0.71	0.71	0.76	1.04	1.44	2.29	2.44	2.46	2.16	2.21	2.07	1.92	1.94	2.21	2.51	2.46	2.49	2.50	2.55	2.51
	Std.Dev.	0.12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.44



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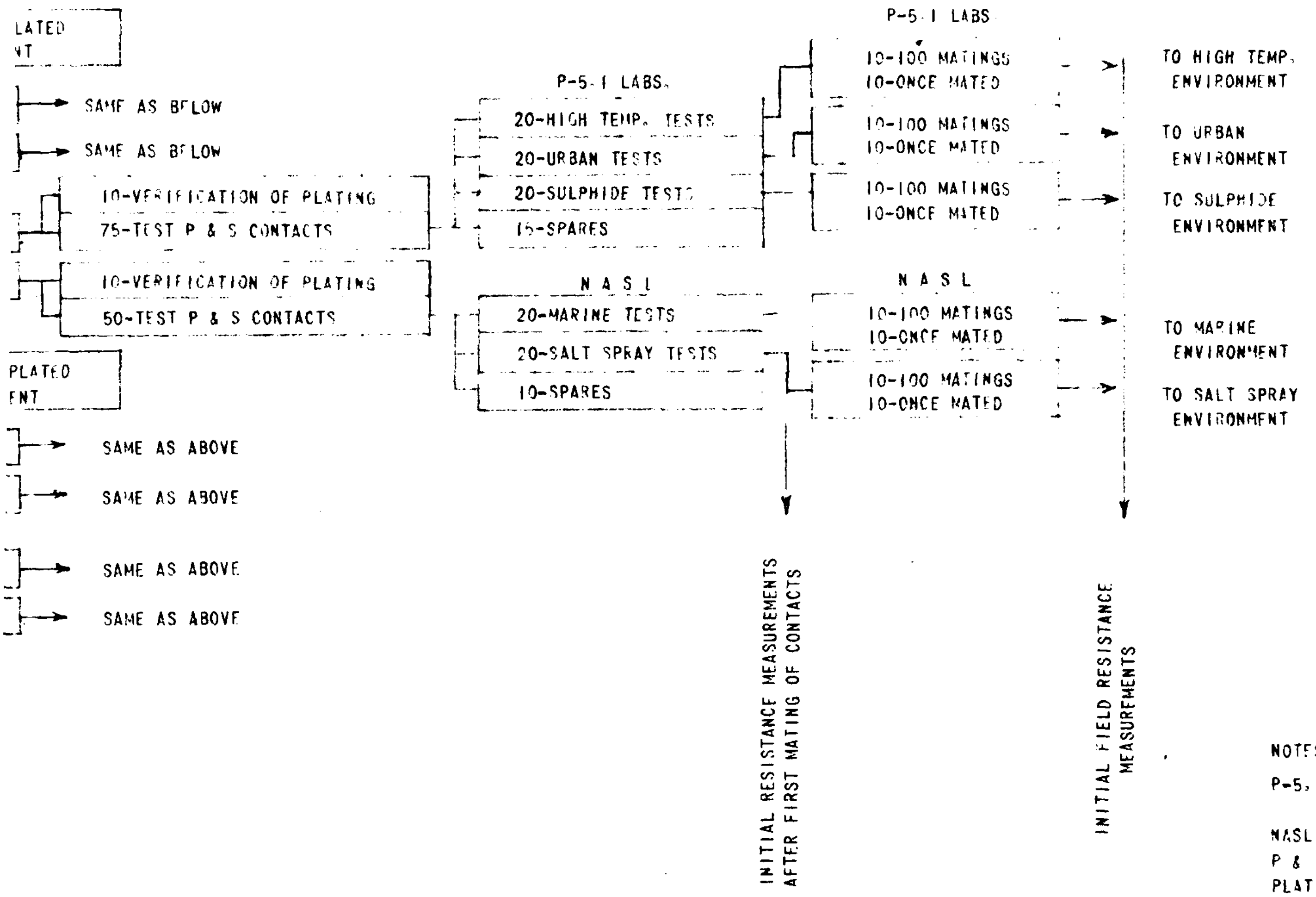
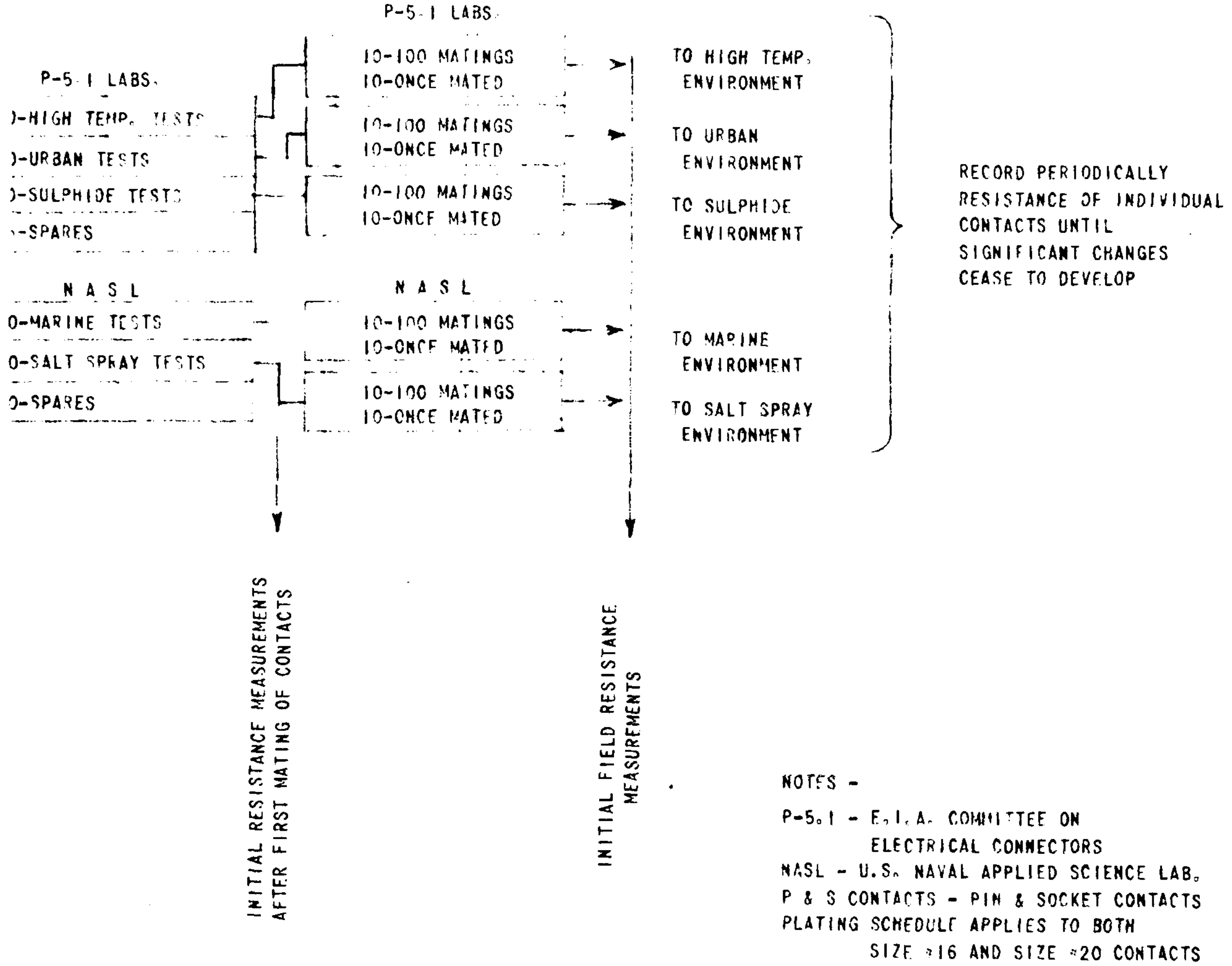


FIGURE 1 - PLATING SCHEDULE



3

FIGURE 1 - PLATING SCHEDULE

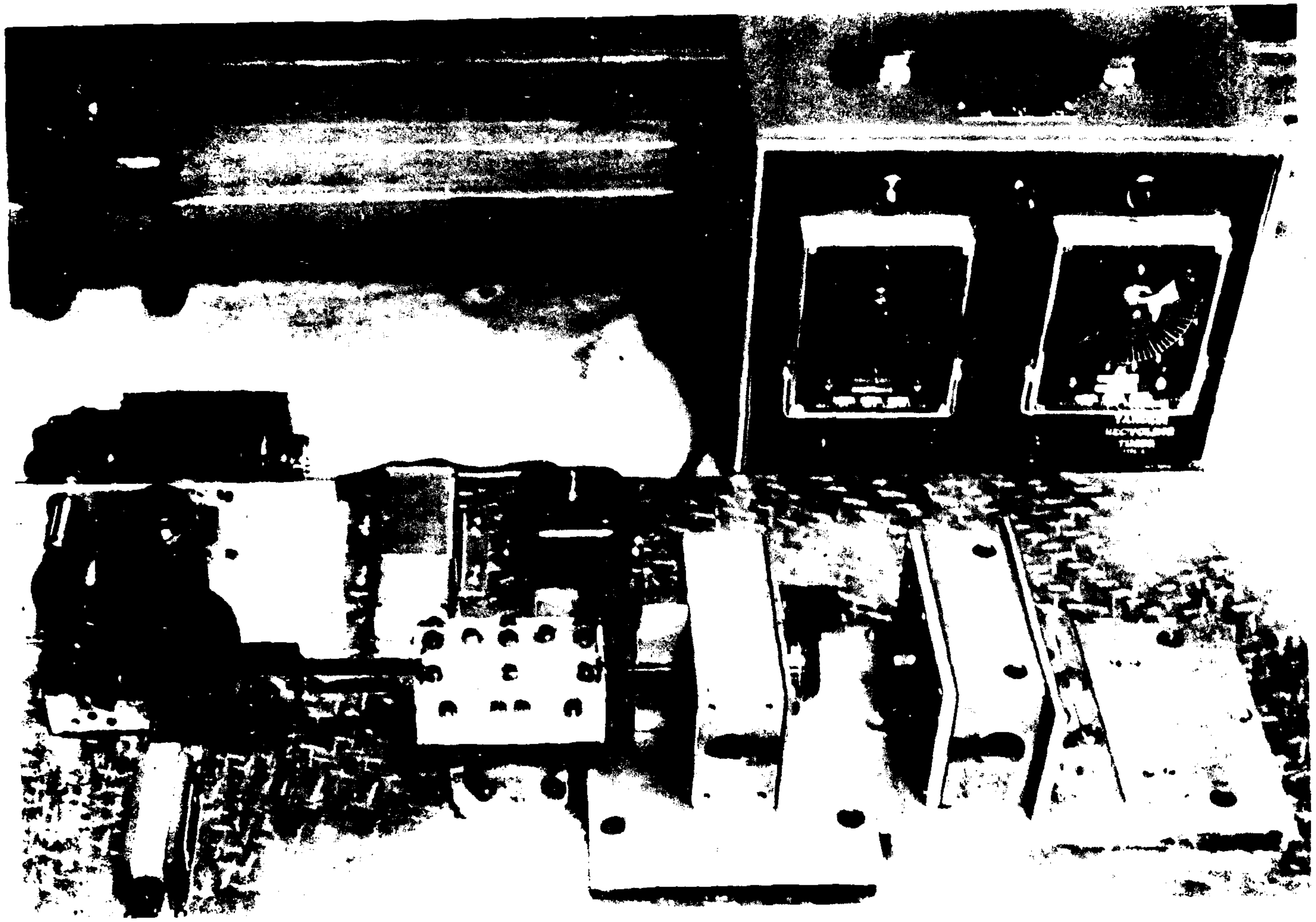


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FIGURE 2 - PRECONDITIONING RECIPROCATING INSERTION AND WITHDRAWAL MECHANISM

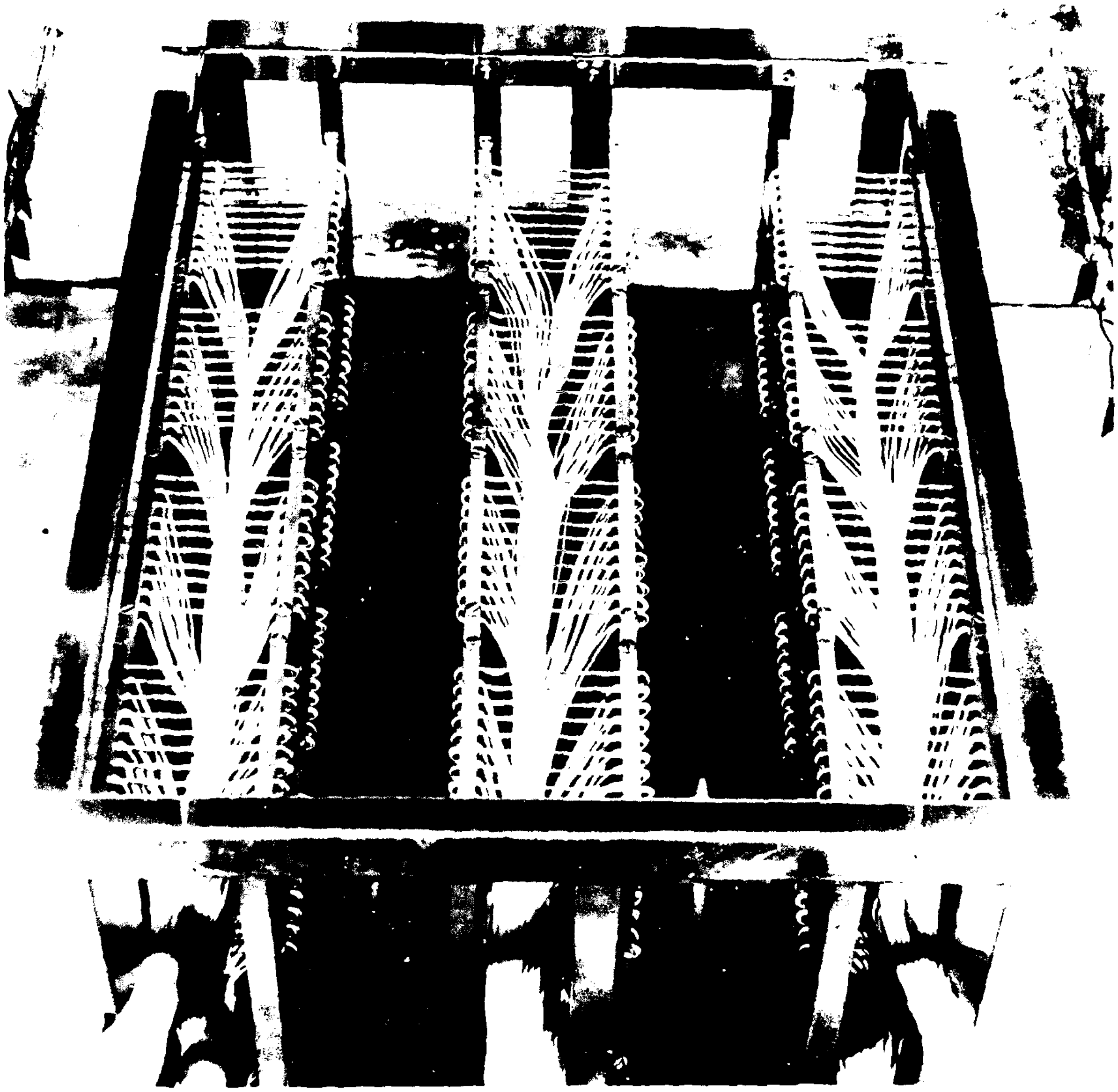

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FIGURE 3 - ELECTRICAL CONTACTS WIRED FIXTURES
ASSEMBLED ON STAND

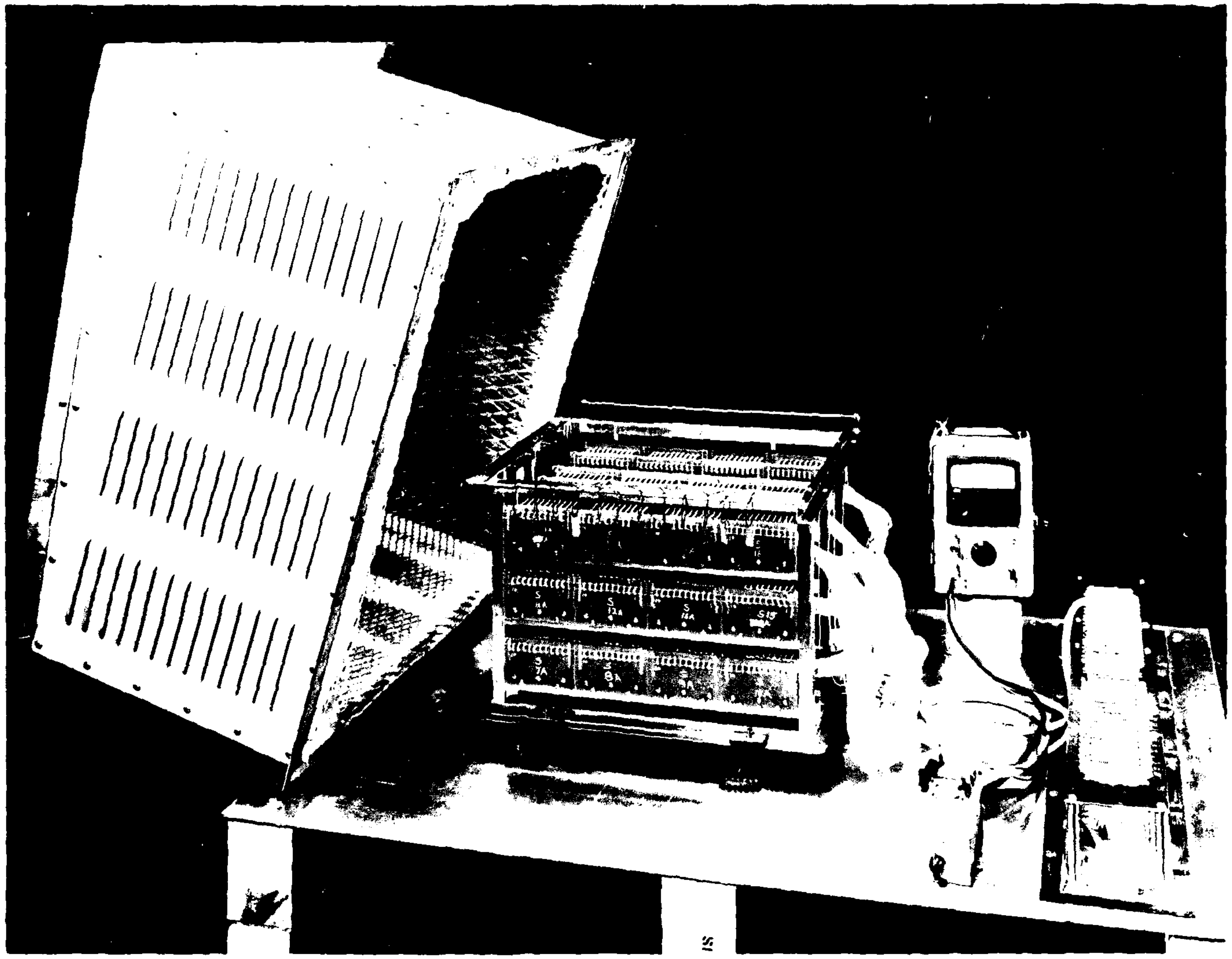

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FIGURE 4 - COMPLETE WIRED ASSEMBLY WITH KEITHLEY MODEL 502A MILLIOHMETER AND 10 POSITION SWITCH

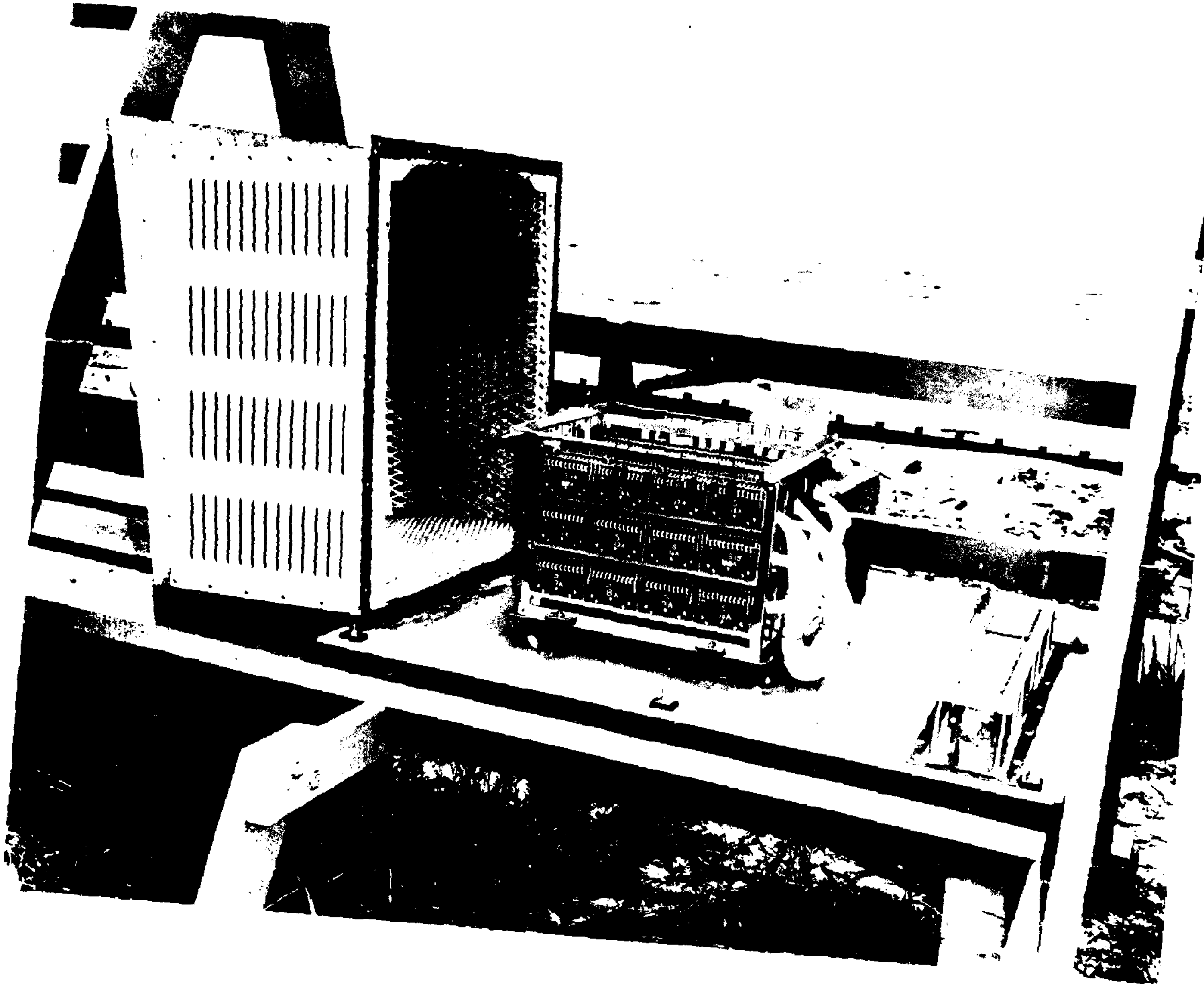

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FIGURE 5 - MARINE ENVIRONMENT EXPOSURE SITE AT FT. TILDEN, N.Y. SHOWING STEVENSON SCREEN WITH GLASS WOOL FILTER

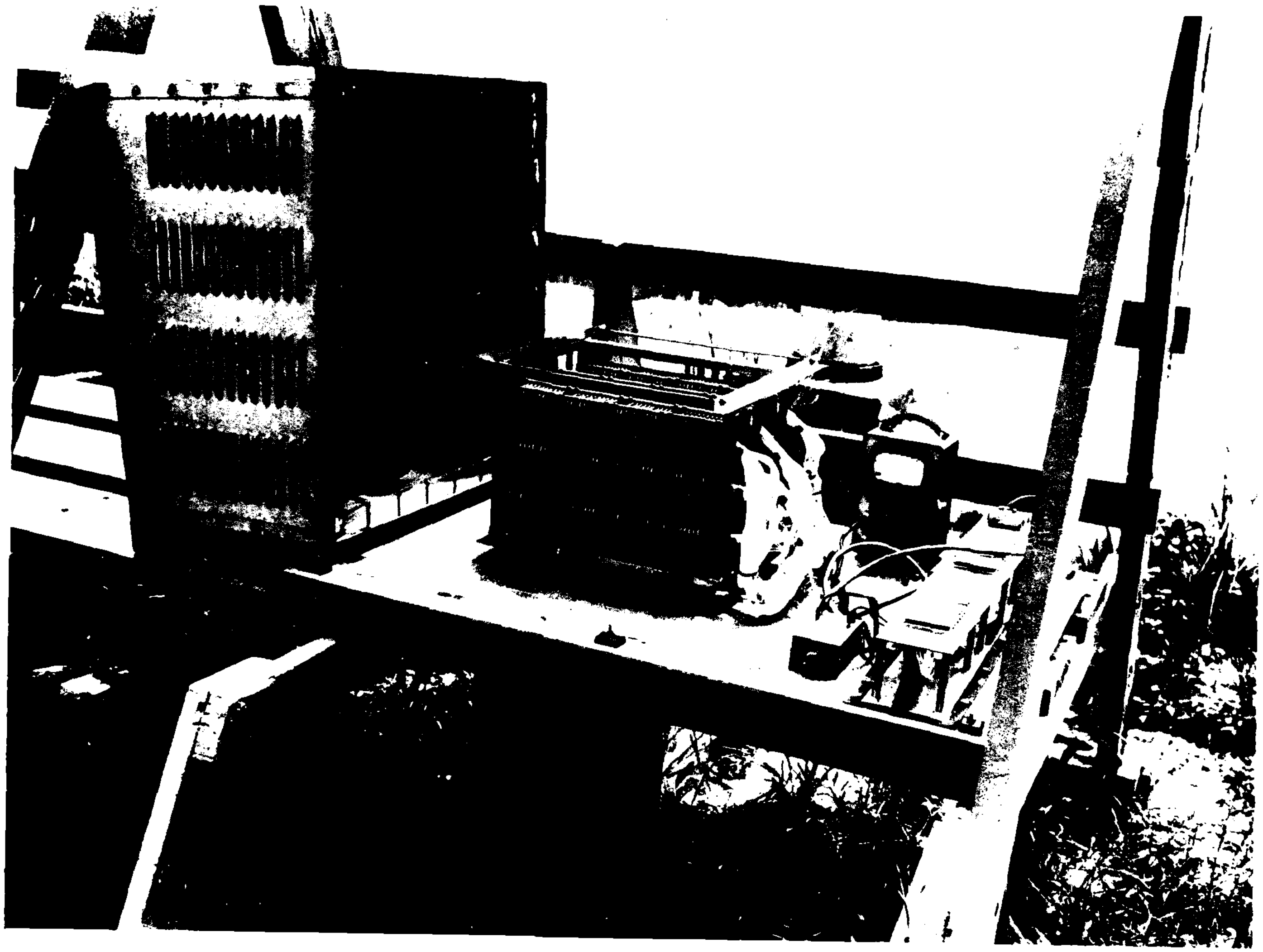

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FIGURE 6 - MARINE ENVIRONMENT EXPOSURE SITE AT FT. TILDEN, N.Y. SHOWING STEVENSON SCREEN WITH STAINLESS STEEL MESH SCREEN FILTER

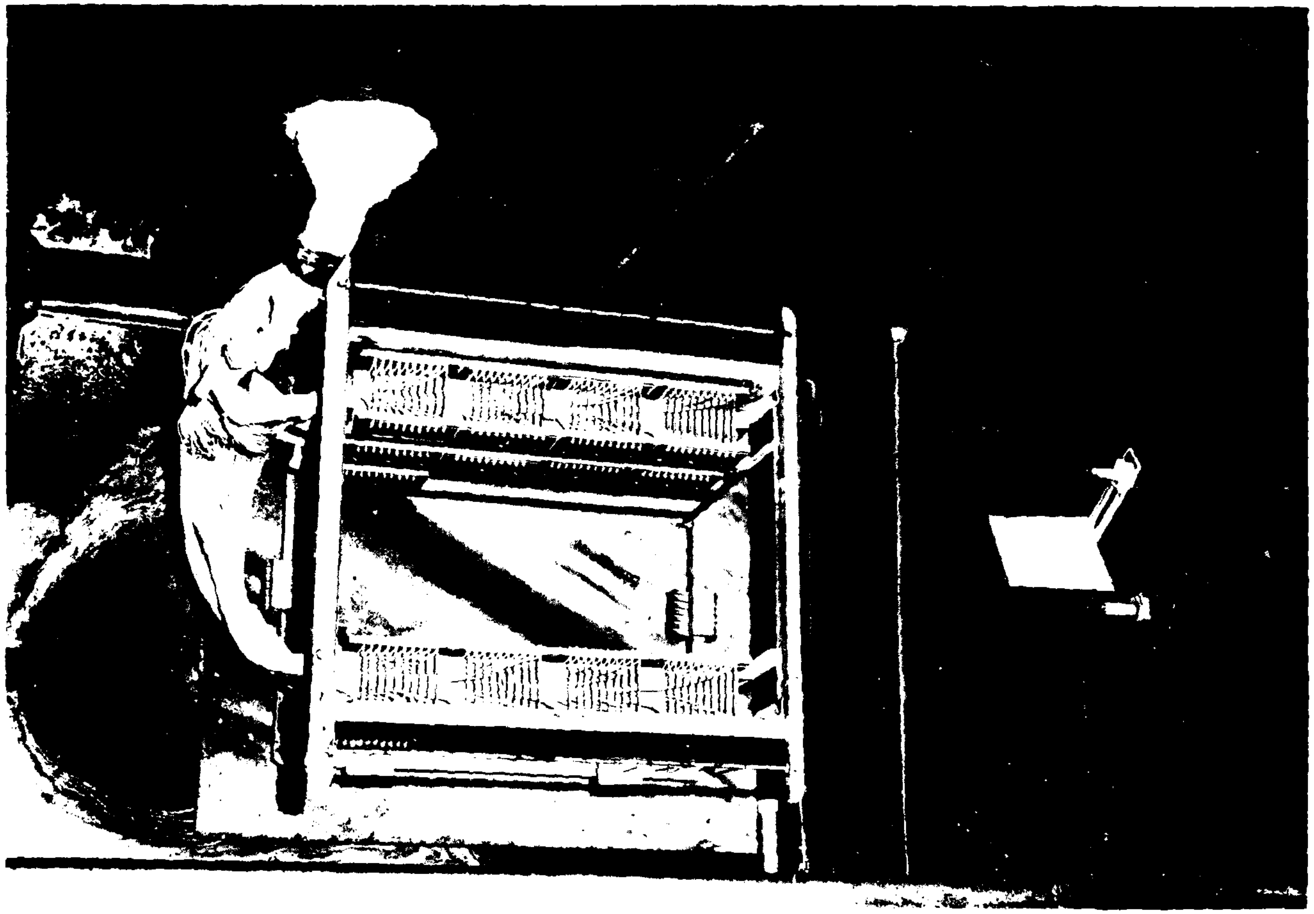

PHOTO L 21039-6

FIGURE 7 - NASL SALT SPRAY EXPOSURE ENVIRONMENT

APPENDIX A

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13. ABSTRACT

Deterioration of noble metal plated electric contacts by marine atmospheres has been determined in the interests of improving reliability and conserving precious metals. EIA, P-5.1 Committee Research Laboratories with this Laboratory investigated effects of marine and laboratory salt spray atmospheres on plated contacts to determine optimum platings. Work described includes establishment of experimental techniques, equipment development, marine exposure site at Ft. Tilden, N.Y., laboratory salt spray environment and procedures. Results indicate nickel underplating is undesirable, 0.000030" of gold over 0.000100" of silver is superior and 0.000030" of gold over 0.000100" of copper is adequate for Naval applications in a marine atmosphere.

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